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Comparison of yields and qualitative characters of spring barley grown after three preceding crops in an organic farming system in the years 2003–2008

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Abstract. The aim of the study was to evaluate yields and selected qualitative parameters of spring barley cultivated after three preceding crops (sugar beet, winter wheat, maize for grain) in the years 2003–2008. farm yard manure was added to the preceding crops at a dosage of 40 t ha^{-1}. A long term stationary field experiment was established on loamy luvi-haplic chernozem in south-western Slovakia. Statistically higher yields were recorded after sugar beet (5.38 t ha^{-1}) than either maize for grain (4.77 t ha^{-1}) or winter wheat (3.54 t ha^{-1}). TGW was statistically significantly higher after maize for grain (43.82 g) compared with winter wheat (42.46 g) and sugar beet (40.93 g). The highest protein content (** $P < 0.01$) was found in the barley crop after sugar beet (12.64%), followed by winter wheat (11.02%) and maize for grain (10.56%). Kolbach's numbers were statistically higher after winter wheat (37.30) than either sugar beet (35.88) or maize for grain (36.12). The extract and starch content was not statistically influenced by the preceding crop.

Key words: spring barley, preceding crops, grain yields, qualitative parameters

INTRODUCTION

In recent decades interest in long-term experiments has increased worldwide, since the indicators of sustainable agriculture able to serve as an early warning system can only be obtained in such experiments. The popularity of organic food and the management of agricultural land according to organic agriculture practices has also been increasing during the last years in the Slovak Republic. The benefits of crop rotation are particularly significant in organic farming systems. Some of them have been already identified, but many of the factors and mechanisms, concerned not only with yields, still need to be better understood. The aim of this paper was to evaluate the effect of three preceding crops (sugar beet, winter wheat, maize for grain) on grain yields and selected qualitative parameters of spring barley, variety Ebson, in the years 2003–2008.

MATERIALS AND METHODS

The stationary field experiment was established in the year 1990 at Borovce near Piešťany town (in the west of the Slovak Republic) on a loamy luvi-haplic Chernozem. This territory has a continental climate with a mean annual precipitation of 593 mm

per year (358 mm during the vegetation period) and with an annual temperature average of 9.2°C (15.5°C during the vegetation period). The area is classified as a maize – barley growing region. The experimental design consisted in a split plot arrangement with two replicates. There were two by six strips of field tested in the experiment: a1) alfalfa - alfalfa – winter wheat – sugar beet – ***spring barley*** – maize for grain, and a2) maize for grain – ***spring barley*** – winter wheat - ***spring barley*** – pea - winter wheat. Farm yard manure at the rate of 40 t/ha was applied to every forecrop. The harvested area of each plot was 75 m^2 (3 x 25 m). The agro technical operations were conducted in accordance with the law NR SR regarding organic farming. The selected variety of spring barley was the variety Ebson. The sowing rate was 400 viable kernels per square meter at a row distance of 125 mm. Experimental plots were harvested at full maturity. Selected qualitative characters (protein content, extract, starch content) were estimated with the NIRS system 6500 method Near Infrared Spectroscopy.

Results obtained were statistically evaluated by variance analysis, differences tested with the Tukey test.

RESULTS AND DISCUSSION

The spring barley performance appeared to be very sensitive to external growth factors, like climate and leaf diseases. The results stress the importance of the actual growth conditions when spring barley performance is evaluated (Askegaard et al., 2006).

In the Central – European conditions of the current experiment the yields of spring barley were significantly influenced by the specific conditions of the monitored years 2003–2006. (Tables 1–2). Significantly lower yields were obtained in the years 2003 (3.61 t ha^{-1}) and 2007 (3.46 t ha^{-1}) in comparison with the other monitored years. Spring barley is a crop with a short vegetation period and a shallow root system. Therefore this crop is very sensitive to lack of precipitation, especially in the spring period. In the critical month of April there was insufficient rainfall in the years 2003 and 2007.

Table 1. Average temperatures in the years 2003–2008 (°C).

Month / Year	2003	2004	2005	2006	2007	2008
January	-1.65	-3.06	-0.48	-4.82	3.47	1.48
February	-1.06	1.28	-2.36	-2.51	4.32	2.46
March	5.17	4.42	3.01	2,1	7.65	4.71
April	9.94	11.65	11.45	11.53	11.32	11.1
May	18.73	14.05	15.62	14.75	16.5	16.84
June	22.26	17.94	18.18	18.99	20.36	21.16
July	21.67	20.06	20.44	22.96	21.28	21.35
August	22.92	20.70	19.12	17.31	20.26	20.72
September	15.88	15.01	16.41	17.21	12.78	15.27
October	7.98	12.22	10.89	12.38	8.64	10.65
November	6.66	5.20	3.68	7.43	2.76	6.55
December	0.88	0.96	-0.33	3.07	-1.0	2.27
Average	10.10	10.04	9.64	10.03	10.72	11.21

Table 2. Average precipitation in the years 2003–2008 (mm).

Month / Year	2003	2004	2005	2006	2007	2008
January	40.9	50.6	39.9	56.1	53.1	25.5
February	9.4	27.4	51.6	30.1	36.2	15.1
March	0.9	49.4	7.0	25.3	56.0	47.8
April	16.5	14.4	91.2	52.7	0.0	31.2
May	8.7	15.5	33.5	66.5	58.9	36.4
June	33.9	72.9	33.7	136.2	55.7	65.9
July	63.3	15.9	96.9	0.5	33.8	89.6
August	16.0	44.6	98.9	83.7	93.6	71.0
September	19.3	38.9	42.3	0.0	109.6	50.5
October	57.9	61.4	10.2	30.0	34.0	33.1
November	34.5	46.5	48.0	49.4	36.2	37.0
December	30.6	33.3	69.5	13.3	32.0	29.0
Sum	541.5	470.8	622.6	543.8	599.1	532.1

Table 3. Grain yields (t/ha) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	4.82	3.83	3.66	4.10a
2004	6.21	5.,96	5.23	5.80b
2005	6.22	4.21	5.40	5.28bc
2006	6.14	2.97	4.58	4.56c
2007	4.28	2,00	4.11	3.46a
2008	6.01	3.54	5.61	5.05bc
Average	5.38a	3.54c	4.77b	4.58

Average values followed by the same letter in each column do not differ significantly at P<0.01.

Table 4. Thousand grain weight (g) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	39.10	43.00	44.05	41.60a
2004	40.6	42.25	42.55	41.80a
2005	42.15	44.8	46.90	44.62b
2006	40.15	39.15	42.80	40.70a
2007	38.05	40.35	40.25	39.55a
2008	45.55	45.20	46.35	45.70b
Average	40.93a	42.46a	43.82b	42.40

Average values followed by the same letter in each column do not differ significantly at P<0.01.

Malting barley requires a preceding crop which leaves the soil in a very good state with a sufficiency of available nutrients (Zimolka, 2006). Grain yields of spring barley were significantly influenced by the preceding crop (Table 3). The lowest yields of spring barley were after winter wheat (3.54 t ha^{-1}), higher yields were after maize for grain (4.77 t ha^{-1}) and significantly higher yields were achieved after sugar beet (5.38

t/ha, ** $P < 0.01$). In tables 4 and 8 the selected qualitative parameters of spring barley, as influenced by the preceding crop and year conditions, are presented.

Thousand grain weight (TGW) was significantly influenced by the preceding crop. TGW was significantly higher after maize for grain (43.82 g) in comparison with winter wheat (42.46 g) and sugar beet (40.93 g). TGW was significantly higher in the years 2005 and 2008 in comparison with the other tested years.

Protein content of spring barley (Table 5) was significantly higher after sugar beet (12.64%) than after maize for grain (10.56%). Slovak Technical Standard STN 46 1100-5 requires a protein content for malting barley from 10.0% to 11.5%. Only spring barley cultivated after maize for grain and winter wheat matched this standard for malting barley.

The extract content (Table 6) is the main criteria for the brewing value of malt. The average value of extract content was 81.27% in the years 2003–2008. The preceding crop did not have a significant influence on the extract content during the observed years of the experiment.

The starch content (Table 7) is a crucial component for extract production and therefore it is a very important standard for spring barley quality. The average starch content was 63.68%; the difference among the preceding crops was not statistically significant.

Table 5. Protein content (%) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	13.26	11.40	10.46	11.71a
2004	12.63	11.95	9.93	11.50a
2005	11.75	9.40	10.22	10.46a
2006	12.51	11.93	12.02	12.15ab
2007	15.23	12.12	11.66	13.03b
2008	10.64	9.34	9.07	9,68a
Average	12.64a	11.02ab	10.56b	11,42

Average values followed by the same letter in each column do not differ significantly at P<0.01.

Table 6. Extract content (%) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	78.20	80.01	80.99	79.73
2004	78.25	79.46	81.09	79.60
2005	91.98	83.51	82.44	85.98
2006	79.99	80.05	79.82	79.95
2007	76.80	79.63	79.77	78.73
2008	82.41	84.21	84.21	83.61
Average	81.27	81.15	81.39	81.27

Table 7. Starch content (%) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	62.39	64.30	64.73	63.81
2004	61.98	62.74	64.82	63.18
2005	63.72	64.96	64.13	64.27
2006	64.60	64.27	64.31	64.39
2007	60.12	63.42	64.05	62.53
2008	64.00	65.09	65.82	64.97
Average	62.80	64.13	64.64	63.86

Table 8. Kolbach's index (WK) of spring barley after different preceding crops.

Year	Sugar beet	Winter wheat	Maize for grain	Average
2003	36.93	37.41	37.48	37.27
2004	37.07	37.35	36.39	36.94
2005	36.69	39.27	36.86	37.61
2006	32.37	35.64	31.44	33.15
2007	36.27	36.77	37.70	36.91
2008	35.93	37.38	36.84	36.72
Average	35.88a	37.30b	36.12a	36.43

The last evaluated character was Kolbach's index which expresses the rate of soluble nitrogen in fresh mash on the total nitrogen in malt (Table 8). The average value was 36.43 units of WK which, according to the Slovak Technical Standard STN 46 1100-5, is considered to be a good value. A statistically higher Kolbach's index value (** $P < 0.01$) was found after winter wheat (37.30 WK) in comparison with maize (36.12 WK) and sugar beet (35.88 WK).

CONCLUSIONS

- Statistically higher yields were achieved after sugar beet (5.38 t ha^{-1}) than after maize for grain (4.77 t ha^{-1}) and winter wheat (3.54 t ha^{-1}).
- Year factors modified grain yields and selected qualitative parameters of spring barley (** $P < 0.01$).
- Thousand grain weight (TGW) was significantly influenced by the preceding crop. TGW was significantly higher after maize for grain (43.82 g) in comparison with winter wheat (40.93 g) and sugar beet (42.46 g).
- The highest protein content was achieved after sugar beet (12.64 %), followed by winter wheat (11.02%), and the lowest protein content was achieved after maize for grain (10.56%). The difference between sugar beet and the other two tested preceding crops was statistically significant (** $P < 0.01$).
- The Kolbach's index was statistically higher after winter wheat (37.30) than after sugar beet (35.88) or maize for grain (36.12).

- The extract and starch contents were not significantly influenced by the preceding crop. The values of these two quality indicators in the organic farming system matched the Slovak Technical Standards STN 46 1100-5.
- The most suitable preceding crop in terms of the required quality standards valid for the conditions of the Slovak Republic was maize for grain (low protein content and higher values of TGW).

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